XXXIIIèmes Journées du développement de l'Association Tiers Monde 2017

Agricultures, ruralités et développement

UNIVERSITE LIBRE DE BRUXELLES

22, 23 et 24 mai 2017

Participatory agent-based simulation integrating local knowledge for co-designing an innovative cattle rearing system in northern Thailand highlands

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Abstract

Efforts to rehabilitate the forest cover in upper watersheds of northern Thailand have led to frequent land use conflicts between government agencies and smallholders belonging to ethnic minorities. Hmong herders exploiting grasslands and fallows with an extensive cattle rearing systems are increasingly constrained by the regular expansion of tree plantations. To mitigate the looming land use conflict between herders and forest agencies, an iterative and evolving process of collaborative agent-based simulation activities was implemented in Nan Province. The communication describes the adaptation of the methodological tools to the context and the outputs of the three successive sequences of activities carried out with the local stakeholders. The result and discussion section focusses on the exchange and integration of local empirical knowledge on the vegetation dynamics and extensive cattle rearing system to co-design interactive simulation tools used to explore innovative land use options accommodating the dual interests of the parties in conflict. A quantitative analysis of the communication among the participating stakeholders also shows how an active sub-group of Hmong herders became gradually the drivers of this companion modelling process.

Keywords

Companion modelling, participatory agent-based simulation, livestock rearing, role-playing game, Thailand.

Introduction

Recent agrarian transformations in upper northern Thailand have led to a rapid deforestation and expansion of commercial agriculture on sloping land subjected to soil erosion risk (Trébuil and Ekasingh 2008). The current efforts to rehabilitate the forest cover in upper watersheds lead to frequent land use conflicts between government agencies and smallholders belonging to diverse ethnic minorities tilling the land without secure land titles (Forsyth and Walker 2008, Fox *et al.* 2009, Walker and Farrely 2008, Sturgeon *et al.* 2013).

This is the case in the highlands of Tha Wang Pha district, Nan province (Figure 1). Here Hmong herders, who have been exploiting grasslands and fallows to manage their extensive cattle rearing systems during the past decades, are increasingly constrained by the regular expansion of tree plantations on this land type also coveted by forest management and biodiversity conservation agencies (Dumrongrojwatthana 2010).

Early separate exchanges with the key stakeholders in this land use conflict have shown that their differing points of view regarding the effects of cattle grazing on the regeneration of the forest cover are rooted in specific knowledge systems produced through their empirical experience and/or education. Foresters and rangers consider that cattle grazing affect negatively the establishment and growth of their tree plantations due to trampling of seedlings and occurrence of bushfires. On the contrary, local herders argue that grazing has a positive effect on the biomass regeneration and the dynamics of the local vegetation cover through a decrease in the risk of bushfire by limiting the herbaceous biomass, and the organic fertilization of the soil provided by the cattle. The lack of an operational communication channel between the two sides led to an increasing tension between them, leading to occasional violent events (burning of foresters' quarters by the herders, shooting of trespassing cattle by rangers, etc.), up to the point that at the start of this project, Hmong herders and local forest conservation agents refused simply to meet.

Based on an initial diagnostic-analysis of the agrarian context and an understanding of the origins of the current land use conflict, a team of Chulalongkorn University (CU) researchers collaborated with their CIRAD colleagues to set up and manage a participatory modelling and simulation process to:

(i) Facilitate the exchange of knowledge and perceptions on the current agrarian dynamics among the key local stakeholders,

(ii) Identify and characterize together a desirable future state of the local agroecosystem accommodating both tree replantation and cattle rearing activities, and

(iii) Co-design the contents of a negotiated collective action plan to move toward that agreed-upon objective.

This communication analyses the successive phases of the collaborative modelling and simulation process implemented in the Doi Tiew village of Tha Wang Pha District, Nan province during 18 months (figure 2). The concerned actors involved in the process ranged from different categories of Hmong herders, to forestry agents from the local forest replantation unit, rangers from the recently established Nanthaburi national park bordering the village farmland, the livestock raising technician, and local administrators at the district level. The succession of complementary methodological tools built during each phase of the process is characterized. The presentation of the results and their discussion emphasize the suitability of such a participatory modelling and simulation process to elucidate and integrate empirical local knowledge in its final products, to engage initially reluctant stakeholders in collective action, and to make use of it to co-design concrete collaborative activities to implement in the field.

Materials, methods and key successive phases of the participatory modelling and simulation process

Preliminary agrarian diagnostic-analysis

Multi-level field surveys were implemented to characterize the recent and on-going transformations of the local agrarian system related to the land use conflict. An agro-ecological mapping of the village agroecosystem visualized its present heterogeneity. The construction of an historical profile of the local agrarian system helped to understand the linkages between land use changes and the strategies of farmers and institutional actors in the recent past. At the family farm level, the diversity of current production systems was assessed based on the relative importance of the cattle rearing sub-system in each category. At the field level, the research team used the extensive diversity of vegetation types available in the landscape mosaic to design an agroecological survey comparing plots with different history in order to document the effects of cattle grazing on the local vegetation dynamics, particularly in young tree plantations established on the village grasslands and fallows over the last two decades.

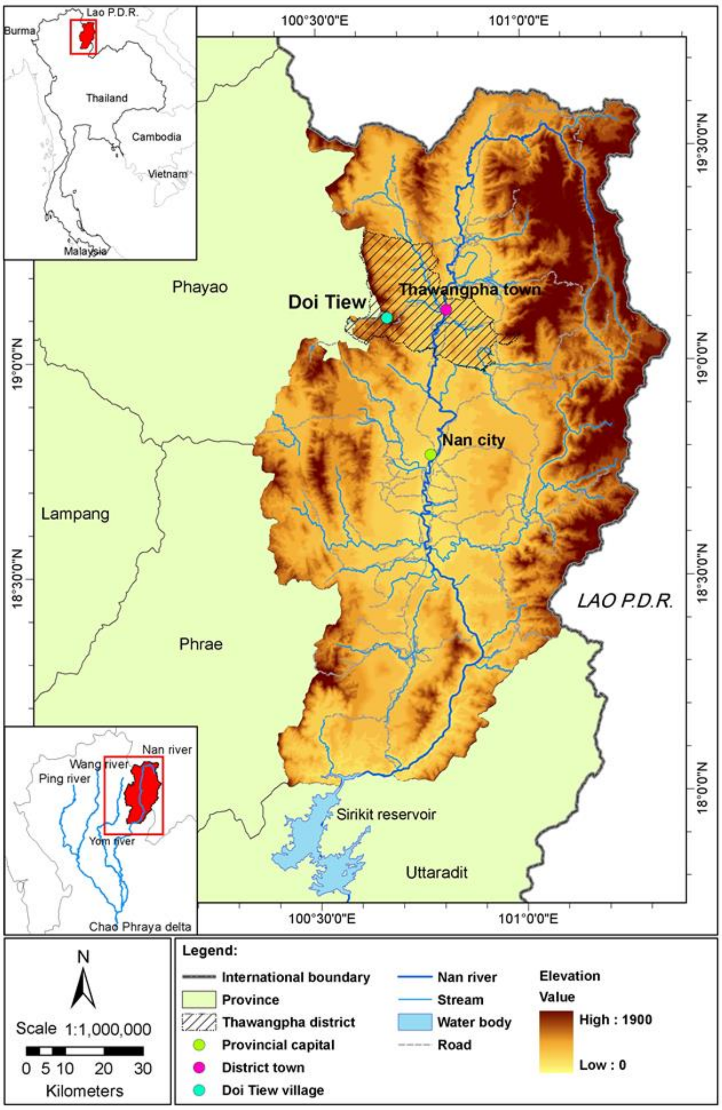


Figure 1. Location of the study site in Nan province, northern Thailand.

Interactive construction of a conceptual model representing the vegetation dynamics at the landscape level

Based on the results from the preliminary diagnostic surveys, the research team initiated the construction of a conceptual model representing the dynamics of the vegetation cover at the landscape level under the influence of human forestry and farming activities. A technique relying on the use of pictograms corresponding to the different types of existing vegetative cover was used to involve small groups of herders and foresters in the construction of the model. Local stakeholders were asked to manipulate the proposed pictograms, and the missing ones they suggested to add, to represent the successions of vegetative cover corresponding to natural or human influenced situations such as: the regeneration of secondary forest, the evolution of shrubby and/or grasslands with or without grazing, etc. Each time, the stakeholders were asked to explain why they selected their proposed series of pictograms by making use of the knowledge they mobilize to make their farming decisions. This interactive method produced the first version of a state-transition diagram representing an agreed upon synthesis on the vegetation dynamics in the Doi Tiew agroecosystem.

Figure 2 displays the set of complementary field and laboratory activities implemented along three successive sequences of the companion modelling (ComMod) process (Antona *et al.* 2003, Ruankew *et al.* 2010), as well as their respective outputs. More information about the contents of these successive activities and steps of the ComMod process is provided below.

Implementation of the conceptual model into a first role-playing game and first sequence of gaming and simulation sessions

The research team implemented this conceptual model into a first role-playing game (RPG) simulating the current land use conflict as a way to validate this model with the local stakeholders. Its board was an abstract representation of the heterogeneities of the landscape mosaic mapped by the agro-ecological zoning of the area carried out during the preliminary agrarian diagnosis (Figure 3). This stylized simulation tool was tested with students to refine its calibration. Later on, the RPG was introduced to a group of herders in a first set of gaming and simulation sessions in the village school. This was an opportunity for the herders to improve the components and rules of the game by sharing their empirical knowledge about the management of extensive livestock rearing systems in such a natural environment.

Figure 2. Overview of the successive phases of the Companion Modelling process implemented in Doi Tiew village of Nan Province, Northern Thailand.

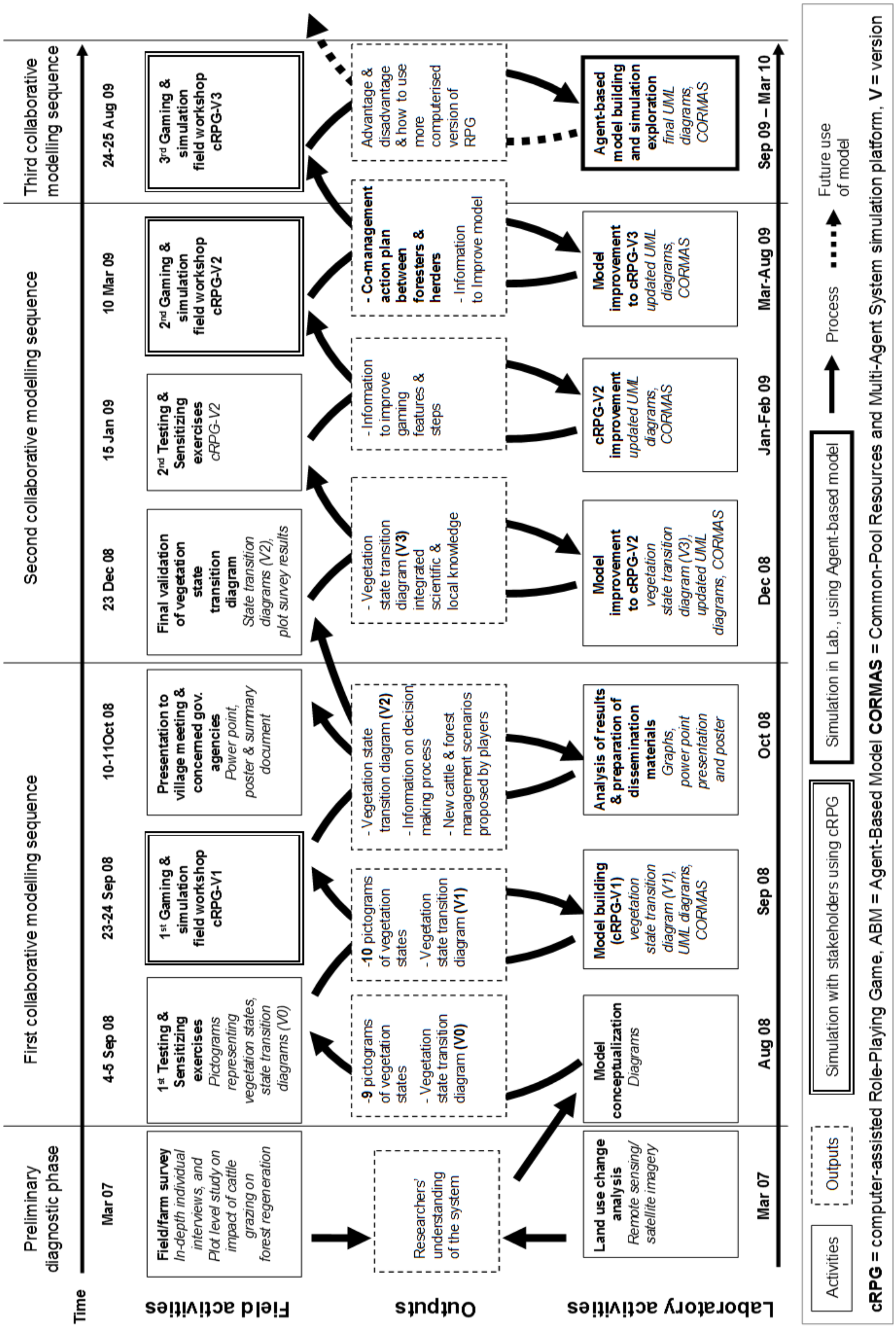
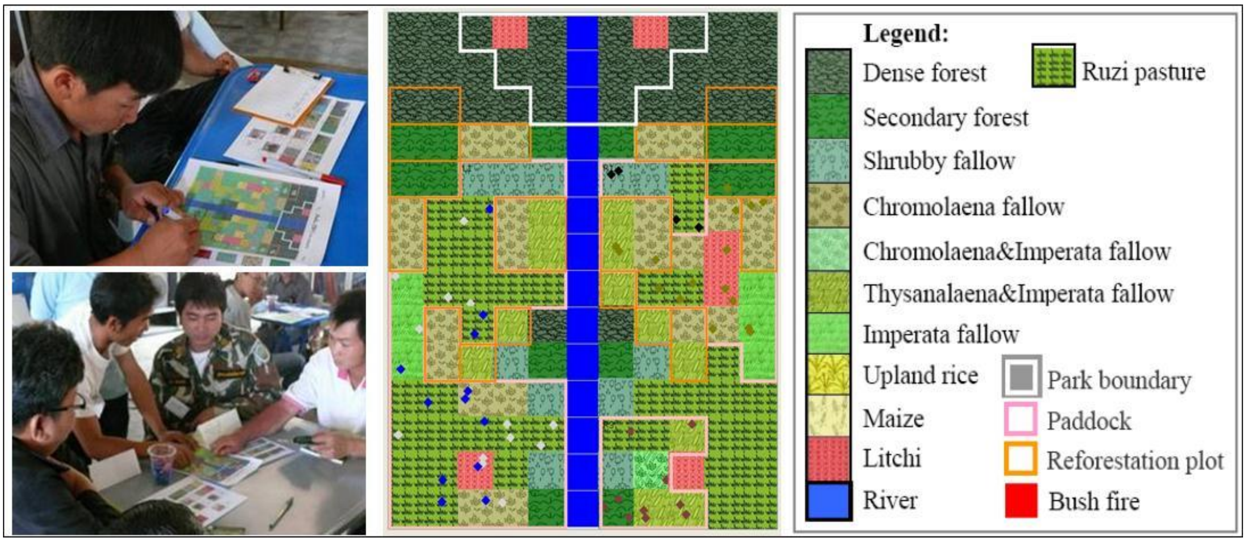


Figure 3. Herders and forest managers during a gaming session using the second version of the simulation tool.



The spatial interface of this agent-based model displays the heterogeneities of land use along a gradient from the remaining protected forest (in the northern part) to the more or less intensively cultivated farm land (in the southern part). The colored dots correspond to the location of the cattle herds. In each successive year of the simulation (or seasonally in the second version of the tool at the request of the participants) the players negotiate the location of their herds and the grazing pressure. The computer model updates the subsequent spatial distribution of the land use categories and provides a refreshed map to the players to make their decisions in the following year (or season in the second sequence).

The following day, a sub-group of herders accepted to meet several foresters, at the district office, a neutral location, for new gaming sessions in which, after introducing the features of the RPG tool to them, the foresters played their actual role. These sessions simulated the current situation and especially the poor sustainability of the existing extensive cattle rearing system facing the advancing reforestation of the natural grasslands and former fallows.

A plenary debriefing took place at the end of the day during which the herders requested the modification of the model and RPG in order to test the introduction of a key technical innovation in their cattle rearing system as a way to mitigate the land use conflict and improve the sustainability of livestock raising in the agroecosystem.

Construction of a modified model and new version of the role-playing game integrating the technical innovation proposed by the Hmong herders

The research team needed to carry out complementary field surveys to characterize and assess the performances of the proposed technical innovation in such highland agroecosystem, i.e. the introduction of *Bracharia ruziziensis* (Ruzi) artificial pastures. These data were used to calibrate and parameterize the introduction of this new kind of land use in the new version of the gaming and simulation tool. Interestingly, we learned that the local livestock technicians have been proposing such an agricultural revolution in cattle rearing for years but without much success. While this time, after experimenting the looming agrarian crisis of their livestock raising activity in the gaming sessions, the Hmong herders found that it was becoming relevant and requested to try this option as a way to secure the continuation of this key livelihood economic activity in their farming systems.

A second cycle of participatory gaming and simulation sessions with the modified tool

The second version of the simulation tool was validated with the local users and used to simulate different land use scenarios and modes of cattle management (individual and pooled herds) to identify the one most acceptable to the concerned stakeholders. Apart from the same group of herders and foresters who were invited to play in the first sequence, rangers from the newly established national park and the district livestock technician also took part in this set of activities. The latter case was a request from the herders who wished to involve an independent observer of the joint decisions made with the foresters following the selection of the most suitable scenario and its translation into a joint field experiment.

Each scenario simulated was assessed by using agro-ecological (like the share of the land converted to tree plantations) and economic (such as the quality of the carcass produced) indicators selected by the participants.

This phase of the process ended with the negotiation between herders and foresters of an experimental protocol to test Ruzi pastures on 10 ha of land provided by the foresters with a herd of cattle provided by large herders and seeds and technical advice provided by the district livestock technician.

Construction of an autonomous simulation tool for out-scaling the process outcomes among the villagers in a third phase

The small group of participants agreed that for the new cattle rearing system to succeed it was necessary to explain to other herders the need for this change of practice and to engage them in its adoption at the village farmland level. To facilitate this herder-to-herder type of training an autonomous agent-based simulation tool playing the modified RPG *in silico* was built. Herders who took part in the process since the beginning were able to use it with the support from a CU researcher to train fellow herders in Hmong language by simulating several scenarios and discussing their results. This time the computer-assisted RPG version was used with herders to input rapidly their decisions by clicking on the spatial interface to select paddock and filling the size of their herds directly in computer. At the herders' request, the tool was modified again to allow the production of upland rice in combination with cattle rearing. Four trained herders, who participated in the activities of the two previous sequences, transferred their knowledge of the model and of the operation of the simulation tool (heterogeneity of vegetation types, cattle dynamics, etc.) to 5 new players. Two scenarios were simulated followed by a plenary discussion on topics such as locating their rice fields close to each other to reduce the risk of damages by cattle, a practice they consider as feasible among farmers belonging to the same clan in the village.

A logbook to facilitate the monitoring and evaluation of the process effects

For the whole duration of this process, an Excel application was designed and use as a monitoring and evaluation to register and analyze (including quantitatively) the exchanges taking place among the different categories of participants. In particular, the evolution of the intensity of the communication among the different stakeholders and the kind of knowledge being shared were recorded. The data were imported in the Netdraw package to visualize the changes of the social networks at work along the successive phases of the process.

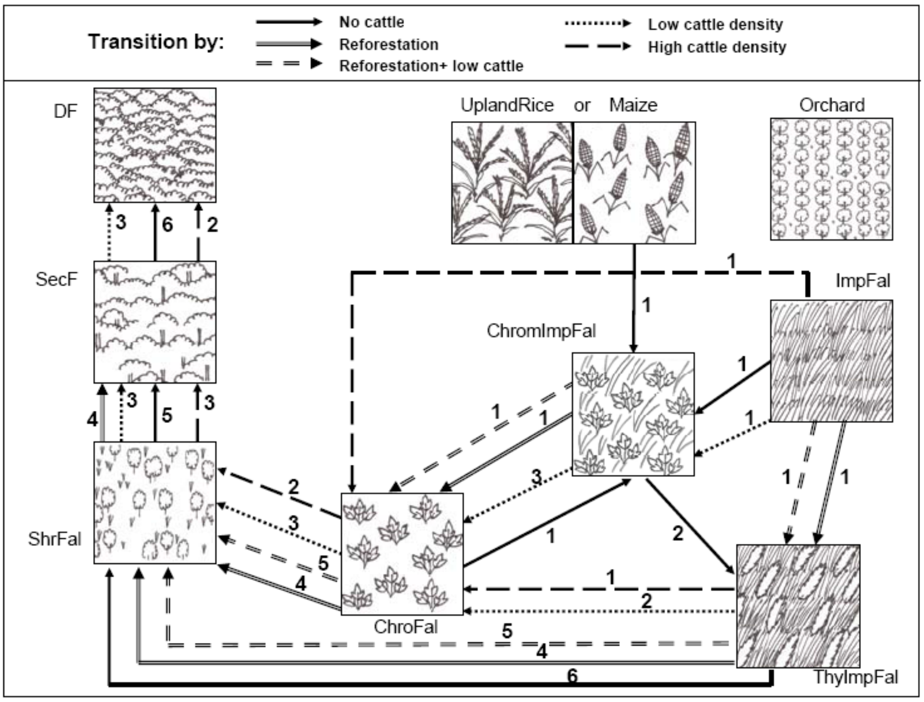
Results and discussion on the use of local knowledge in co-designing an innovative system

The integration of different aspects of the local empirical knowledge resulted in the co-design of successive versions of the simulation tool. Its components and rules were very significantly influenced by this kind of knowledge system as explained below.

Integration of local knowledge on vegetation dynamics

Both foresters and herders co-constructed the conceptual model of vegetation state transition. The Hmong herders requested to add a new pictogram representing the "imperata fallow" in the initial set of pictograms proposed by the research team. This key indicator of forage production degradation, as well as its linkages with other vegetation states according to them, was integrated as a component of the improved vegetation state-transition diagram of the conceptual model as shown in figure 4.

Figure 4. Vegetation state-transition diagram with integrating the "Imperata fallow" (ImpFal) type proposed by the local herders.



Note: DF = Dense forest, SecF = Secondary forest, ShrFal = Shrubby fallow, ChroFal = Chromolaena fallow, ThyImpFal = Thysanolaena and Imperata fallow, ChroImpFal = Chromolaena and Imperata fallow, ImpFal = Imperata fallow, and the numbers indicate the successive time (in year) for updating vegetation states. In this extensive cattle raising system in reforestation area is low intensity

At this early stage, the local foresters shared their reforestation strategy and practices to be taken into account in the model design, particularly the establishment of one additional new tree plantation plot per year, and the change from monospecific plantations in the past to a mixture of different species planted on the same plot (Dumrongrojwatthana 2010).

Integration of local knowledge on extensive cattle rearing system

Table 1 describes the rules implemented in the cattle dynamics module of the model.

Table 1. Rules used in the implementation of the cattle dynamics module of the model.

				Cattle status
	Grazing level	Paddock size (cells)	Number of suitable cells (“*ImpFal*”, “*ThyImpFal*”, “*ChromImpFal*”)	
Update cattle status	Low (cattle density <= 2.4 head/cell)	> 10	5-6	fat
		> 10	3-4	normal
		<= 10	3-4	normal
		<= 10	1-2	thin
	High (cattle density >2.4 head/cell)			thin
	Herd size		Cattle status	**Number of newborn/year**
Reproduction	5-14		Fat/normal	3
			Thin	2
	15-25		Fat/normal	4
			Thin	3
	>25		Fat/normal	8*
			Thin	5
	Herd size		**Proportion of chance card to be used **** (Number of cattle : number of card)	
Mortality	<=25		0:2, 1:4, 2:4	
	>25		2:2, 3:4, 4:4	

* Because in this extensive system the proportion of female animals is higher in large herds according to local herders, the number of newborn calves was set to reflect this fact.

** Small herd size has a lower risk of mortality compared with a large one according to local herders.

These criteria (grazing level/pressure per type of vegetation, type of suitable vegetation cover for grazing, cattle reproduction rate, etc.) were discussed and setup based on the empirical experience of the herders. In particular, the herders increased very significantly the rate of loss of cattle due to predators and accidents proposed by the researchers to better fit with their empirical knowledge.

Because both individual and collective cattle management practices are used in this village, these two options were also taken into account in the design of scenarios to be simulated with the participants during several gaming sessions. The fact that, after debating their relevance, the research team was integrating most of the local stakeholders' suggestions in the construction of the simulation tool was instrumental in improving the communication among the participants and the confidence of the herders in a simulation tool tailored to the specificities of their context, practices and needs.

At the end of the first sequence, a small majority of the participating herders were clearly engaged in the collaborative agent-based simulation process. By accepting to use the tool with the foresters in the neutral ground of the Tha Wang Pha district administrative office, they opened a communication channel and dialogue between the two parties in conflict that did not exist before. In the final gaming session of this sequence, the herders proposed the introduction of a new and more land intensive cattle rearing system with the potential to allow the continuation of both their livestock rearing activity and the rehabilitation of the tree cover in the upper watershed.

Integration of a technical innovation proposed by the Hmong herders and modification of the computer-assisted simulation tool used in the second sequence

The results of the gaming sessions based on the existing practices played in the first sequence showed clearly the lack of sustainability of the cattle rearing activity because of the gradually shrinking area of natural pastures and the expansion of young tree plantations. In the final plenary debate of this sequence, the herders proposed to introduce artificial pastures of *Bracharia ruziziensis* (Ruzi) in the landscape to boost forage production. Interestingly, this technique has been proposed by the local extension system for years but has not been adopted so far in this higher part of the region. Now the participating herders saw it as a potentially relevant way out of the looming crisis of their livestock rearing system.

At the end of the field workshop, the research team was asked to modify the conceptual model of the simulation tool to accommodate the establishment of Ruzi pastures, and to change the time step of the decisions made by herders from annual to seasonal (wet and dry seasons) when running a simulation. Following a short survey on the characteristics and performances of Ruzi pastures in such an environment, the computer-assisted RPG was adjusted accordingly (see on the spatial interface in figure 3).

Because their trust in the local foresters was still limited, the herders also proposed to invite other stakeholders to take part in the subsequent field workshop of the second sequence based on the modified simulation tool to witness the exchanges between the two sides of the land use conflict and their respective eventual commitments.

The second field workshop simulated land use scenarios with foresters choosing reforestation plots and herders establishing Ruzi pastures and locating their herds in paddocks delimited on the spatial interface of the computer-assisted simulation tool (Dumrongrojwatthana 2010). Both individual and pooled types of management of the cattle were tested. The agro-ecological and economic indicators selected to assess the results of the different scenarios were the area under the main types of land use (forest, shrubby fallow, other fallows, crops, ruzi pastures) and the number of cattle heads and the quality of their carcass (fat, normal or thin) respectively.

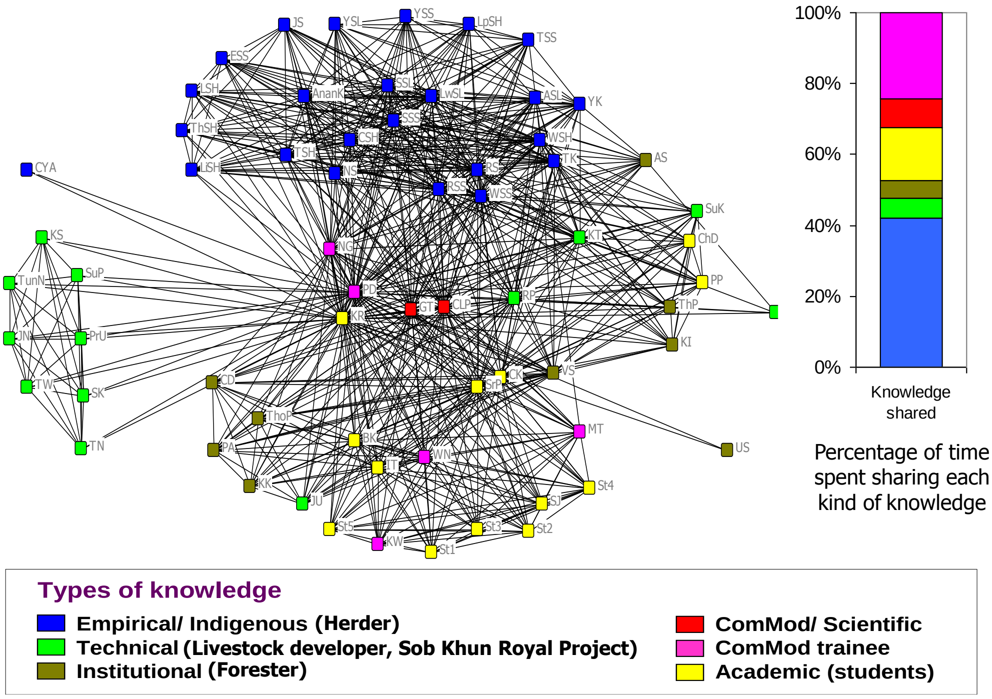
The analysis of the simulation results showed the superiority of the "pooled management" option and the effectiveness of the "ruzi pasture" technical innovation to feed the cattle and to produce quality carcasses. Therefore, the stakeholders moved on the definition of an experiment to text this option in the field. The foresters accepted to allocate a plot of 10ha for this purpose, and herders with large herds committed to provide the cattle needed to implement it, while the livestock technician volunteered to give Ruzi seeds and technical advice for pasture establishment (Dumrongrojwatthana 2010).

Effects on the communication among participating stakeholders and importance of local knowledge in the exchanges

The analysis of the logbook data for the whole duration of the gaming and simulation process showed that more than 40% of the time spent exchanging knowledge and perceptions among the participants was about the local herders' empirical knowledge (figure 5). This confirmed the efficiency of such collaborative agent-based simulation activities to mobilize the frequently neglected local knowhow, in interaction with other types of knowledge, when co-designing innovative land use systems.

The social network, for the whole process, presented in figure 5 also shows that, if the interactions among the participating herders were direct and numerous, the interactions with the foresters and other kinds of stakeholders occurred mostly through the core members of the ComMod team managing the process. This was expected because the two parties in conflict refused to communicate at the start of this process, and because many past ComMod processes underlined the key role of honest broker played by the organizers and coordinators of such field workshops.

Figure 5. Intensity of communication and type of knowledge exchanged among the participants during the companion modelling process in Doi Tiew village, Nan province, northern Thailand.



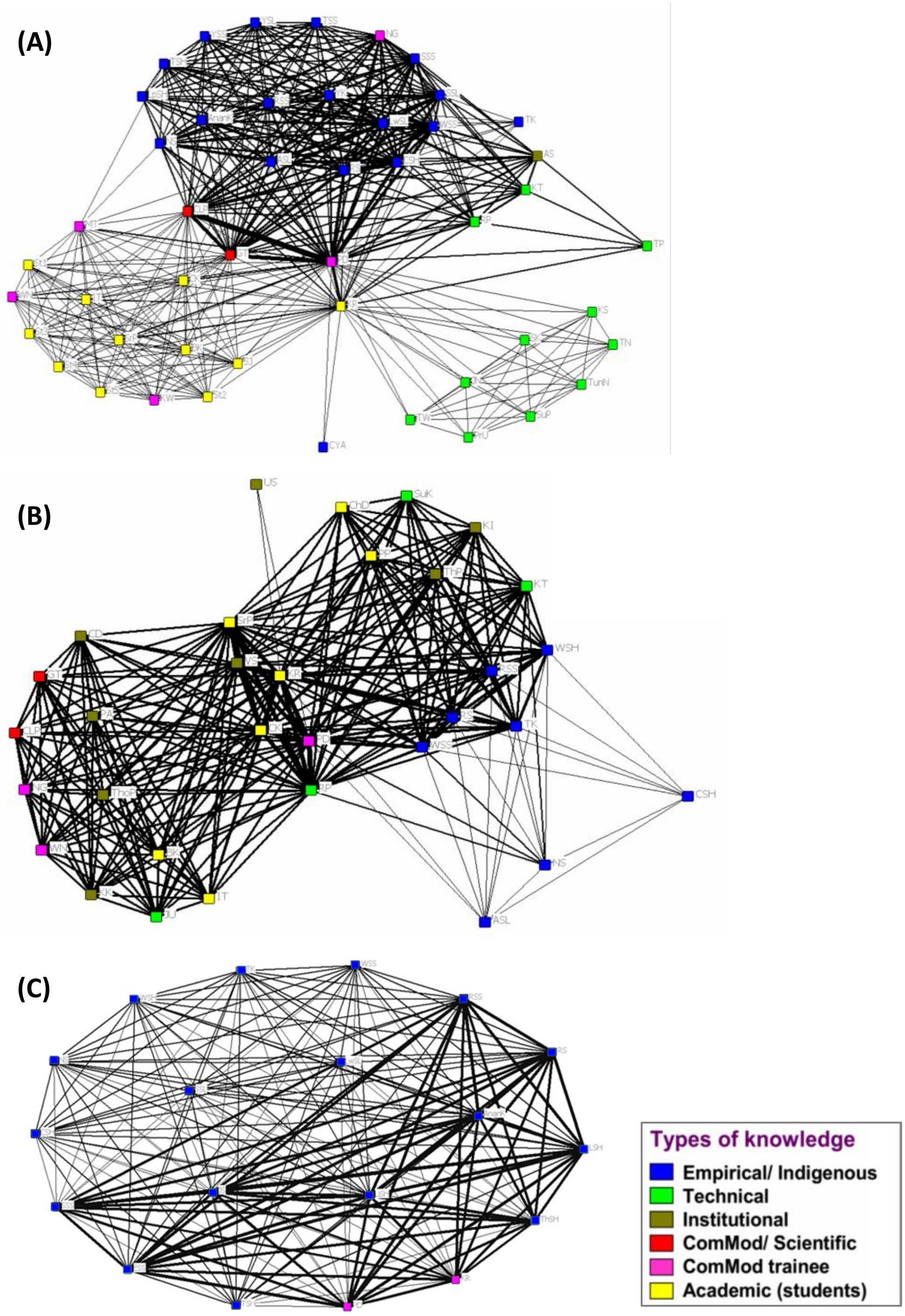
To see if this situation improved from the first to the second sequence, the logbook data was separated sequence wise and similar graphs built to visualize how knowledge sharing operated in the successive three phases of the process.

Figure 6 shows that in the second sequence (B) the intensity of direct exchanges between a sub-group of herders (those who accepted to face the foresters in the second field workshop) and the foresters increased, but the ComMod team members still played an important role in facilitating the exchanges. In the final sequence (C), the shape of the network clearly shows the dominating role of the group of trained herders managing the knowledge exchanges. The couple of ComMod team members operating the autonomous agent-based model used in the simulation of scenarios at the request of the trained herders are pushed to the periphery and do not play a central role anymore.

The successive phases of this ComMod process have gradually empowered a dynamic sub-group of young Hmong herders from Doi Tiew village who gradually became the drivers of the process. They participated actively in the co-construction of the first simulation tool, then they proposed a key technical innovation that could trigger a local agricultural revolution based on artificial pastures, and finally they engaged themselves in the dissemination of their new knowledge and outputs of the simulations among the other villagers for community mobilization.

Thanks to the selection of adapted methodological tools and techniques (manipulation of pictograms to co-design a conceptual model, “non-threatening” role-playing sessions to facilitate communication and knowledge sharing, etc.), their lack of formal educational background was not an obstacle to the use of relatively simple agent-based models very much related to their actual circumstances and farming practices.

Beyond their significant contribution in the design of the first simulation tool, they continued to request adjustments (by introducing Ruzi pastures in the second sequence, then upland rice production in the third one). They corresponded to new questions arising from previous exchanges, continuous learning, and to their willingness to use the co-designed simulation tool to explore new possible land use options. The flexibility of multi-agent modelling approach is a key advantage to be able to adapt the agent-based simulation tools at the speed of their requests along such iterative but evolving ComMod process.



Note: line thickness is proportional to time spent interacting.

Figure 6. Exchanges of different types of knowledge among the participating stakeholders in the three successive sequences of the companion modelling process in Doi Tiew village, Nan province, northern Thailand. (A) Sequence 1 (herders, foresters, research team), (B) Sequence 2 (herders, foresters, research team, livestock technician, park rangers, project officers), (C) Sequence 3 (herder-to-herder training with researcher).

Conclusion

The collaborative landscape modelling and simulation activities, implemented with local stakeholders who initially refused to meet and discuss, established a communication channel between herders, foresters and rangers. The dialogue led to an improved mutual understanding of their respective perceptions of land-use dynamics, objectives and practices. The improvement of trust between the villagers and the forest conservation agencies was also noticeable and translated into the design of a joint field experiment on artificial pastures. This was a significant step toward a concrete assessment of the proposed technical innovation in actual farming circumstances. Such a collective plan was beyond the role assigned agent-based simulation activities. Nevertheless, they played a key role in the identification and negotiation of a local land use system acceptable to the parties in conflict and accommodating their respective interests.

This case study also demonstrates the complementarity between the results of an in-depth multi-level agrarian system diagnosis and subsequent participatory activities facilitated by simple models to mitigate an existing land use conflict by changing the technical use and mode of access to renewable natural resources. In this ComMod process, the Hmong herders proposed nothing less than an agricultural revolution based on the introduction of artificial pastures to adapt their agrarian system to environmental change and particularly the rehabilitation of the forest cover in their upper watershed.

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